6.3 An n-type silicon sample contains a donor concentration of $N_d = 10^{16}$ cm^{-3}. The minority carrier hole lifetime is found to be $\tau_{p0} = 20$ μs. (*a*) What is the lifetime of the majority carrier electrons? (*b*) Determine the thermal-equilibrium generation rate for electrons and holes in this material. (*c*) Determine the thermal-equilibrium recombination rate for electrons and holes in this material.

- First, find the electron concentration at thermal equilibrium.

From Table B.4, $n_i = 1.5 \times 10^{10}$ #/cm^3 for Si @ 300K

Since $N_d >> n_i$, $n_o \simeq N_d = 10^{16}$ #/cm^3

Per (4.43), $p_o = \frac{n_i^2}{n_o} = \frac{(1.5 \times 10^{10})^2}{10^{16}} \Rightarrow p_o = 22{,}500$ #/cm^3

a) For equal recombination rates,

(6.35) $R = \frac{n}{\tau_{nt}} = \frac{p}{\tau_{pt}} \Rightarrow \tau_{nt} = \frac{\tau_{pt}}{p} n$

$\tau_{nt} = \frac{20\mu s}{22{,}500} 10^{16} \Rightarrow \tau_{nt} = \tau_{no} = 8.889 \times 10^{6}$ s

$\Rightarrow$ Electron last a long time since they vastly outnumber the holes.

b) At equilibrium, $G_{no} = G_{po} = R_{no} = R_{po}$

$G = G_{po} = \frac{p_o}{\tau_{po}} = \frac{22{,}500 \text{ #/cm}^3}{20 \times 10^{-6} \text{ s}} \Rightarrow G = 1.125 \times 10^9 \frac{\#}{cm^3 \cdot s}$

c) At equilibrium, $G = R$

$R = 1.125 \times 10^9 \frac{\#}{cm^3 \cdot s}$